Revolutionary oxygen impulse technology for steel production

From experiment to large-scale industrial use

An application report by Dr Rainer Klock and Marcel Mokosch

thyssenkrupp AT.PRO tec GmbH is well known for the development of the sequence impulse process. When used on cupola furnaces, it considerably increased their cost-effectiveness in the past. In over 10 years of development work with Schubert & Salzer as their partner, Dr Rainer Klock and the team at AT.PRO tec succeeded in getting the SIP technology to work on blast furnaces, too, with the help of sliding gate valves. The story of a researcher on the way to becoming a plant manufacturer.

The history of the blast furnace process is a long story of great innovations and technical improvements. Again and again, there have been courageous innovators who were willing to question common methods in order to further optimise the production process of pig iron. In the 18th century, for example, Abraham Darby succeeded in using coke instead of charcoal. As a result, blast furnaces became considerably larger and more efficient. In the 19th century, Edward Alfred Cowper managed an innovation leap with the newly emerging blast preheaters. Today the so-called “Cowpers” are part of every blast furnace plant.

Utilising the “sequence impulse process with induced shock waves”, the blast furnace has now reached the next stage in its evolution. Behind the SIP are thyssenkrupp AT.PRO tec GmbH and its present managing director, Dr Rainer Klock. As a team, they developed the technology over a period of more than 10 years in such a way that its use at the blast furnace became possible at all. Today the employees at AT.PRO tec bundle highly specialised expert knowledge from science and industry for the use of gases in melting processes.

The basic concept of the new process is to activate the areas deeper inside the furnace. In the standard process technology, a cone of coke is created - the so-called “dead man”. Incompletely reacted fine particles block this coke bed. The gas flow and heat cannot penetrate deeply enough into the furnace.

The solution: strong intermittent impulses to enable the necessary deep penetration of the technical oxygen. This leads to a short-term, local surplus of oxygen and a more complete chemical conversion of the fine particles – even deep inside the coke bed. The shock waves associated with the impulses break open

Dr Rainer Klock from thyssenkrupp AT.PRO tec (right) with Marcel Mokosch from Schubert & Salzer Control Systems (left).

blockages at this point and mix the contents by means of strong turbulences. They ensure a more homogeneous gas distribution and a better flow-off of the molten metal and the slag.

Phase 1: ASIPGO – the collaborative research project of thyssenkrupp and RWTH Aachen (2007-2011)

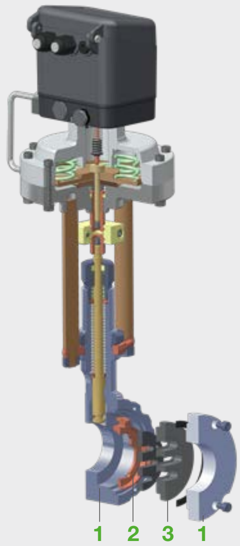
The technology has been working successfully for years on a smaller scale in cupola furnaces and enables a considerable increase in cost-effectiveness. Use on the much larger blast furnaces was, however, still completely unresearched.

When AT.PRO tec approached RWTH Aachen and the Institute of Ferrous Metallurgy (IEHK) situated there with the subject, Rainer Klock had just completed his degree thesis. RWTH looked for research associates for the new research project, which was supported by thyssenkrupp as the industrial partner. “That was the perfect opportunity for me. Not only was I able to write my doctorate thesis directly following my degree, the project also offered me the possibility to work on one of the largest blast furnaces in Europe”, said Dr Klock later. “The ASIPGO project was intended to pursue two goals over a period of three years: firstly to improve the use of SIP on cupola furnaces through automation and secondly to enable the use of SIP on blast furnaces."

Within the framework of his doctorate thesis, Rainer Klock focused on research into use on the blast furnace. First of all, the physical and chemical processes were examined that made the SIP successful on the cupola furnace. The research group, consisting of employees from thyssenkrupp AT.PRO tec, thyssenkrupp Steel Europe and RWTH Aachen, wanted to understand the processes in the raceway zone of a blast furnace and how they would probably be affected by oxygen impulses in order to be able to transfer the technology from the cupola furnace to the blast furnace with the collected knowledge.

On the basis of these findings at the IEHK, a SIP test system for blast furnaces was finally constructed. Compared to the SIP system for cupola furnaces, significantly larger nominal diameters and pressures were now used. The system therefore had to be adapted and equipped with suitable components. One of the main focal points was the so-called pulse valves. These had to be capable of generating the strongest possible shock wave. Following a long series of investigations with different types of valve, the sliding gate valve from Schubert & Salzer was selected.

The principle of this valve was fascinatingly simple: two slotted discs that slide over each other and seal against each other. A sealing plate, fixed perpendicular to the direction of flow on which another movable disc with the same slot arrangement is moved, changes the flow cross-section. The applied pressure difference presses the movable disc against the fixed disc and thus contributes to leak-tightness. The short opening times achievable by this principle and the pressure resistance with large nominal diameters were ultimately decisive.

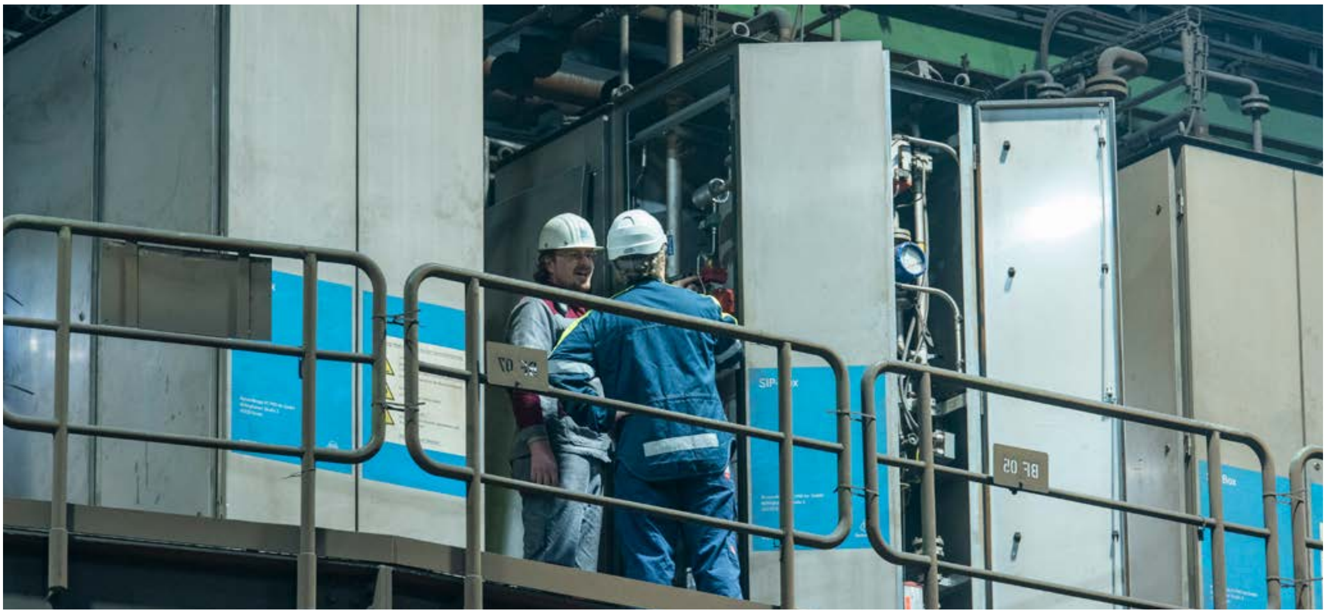


Principle of the sliding gate control valve:
A sealing disc (**2**) fixed in the body (**1**) at right angles to the flow direction has a certain number of crossways slots (**3**). A moving disc (**4**) with the same arrangement of slots moves parallely to the fixed disc, thereby changing the flow cross section. The prevailing differential pressure presses the moving disc (**4**) against the fixed disc (**2**) and seals it.

Phase 2: From experiment to large–scale industrial use (2011 – 2020)

The first tests with the SIP test system on the Schwelgern 1 blast furnace yielded such promising results that thyssenkrupp Steel Europe decided to further develop the process beyond the research project. With its hearth diameter of 13.6 m, a total

Schwelgern 1 is one of the world's most modern blast furnaces with a potential output of 10,000 t per day. Over the course of the project, 40 SIP boxes (grey-blue in the photo) were installed on the tuyeres. The boxes inject strong intermittent impulses with technical oxygen into the coke bed in order to achieve the best possible penetration.



The SIP boxes are the result of many years of research and development: from the first tests at the Institute of Ferrous Metallurgy at RWTH Aachen, to the construction and optimisation of a prototype on the blast furnace in Schwelgern, to the installation of the complete SIP system during running operation.

height of approx. 110 m and an internal volume of 4,416 m³, the Schwelgern 1 blast furnace has a potential output of 10,000 t per day. The welded steel construction, which is lined inside with refractory material and has a closed cooling water circuit, is one of the most modern blast furnaces in the world. Rainer Klock was to manage the further development of SIP as plant engineer and was appointed by thyssenkrupp Steel Europe towards the summer of 2010.

Whilst an industrially operational prototype had to be created on the basis of the SIP test system, this prototype was to be further optimised for the process. “In order to further improve the effect of our process, we began to dedicate ourselves to the shock waves associated with each impulse,” explained Dr Rainer Klock, now a doctor of metallurgy. “We were convinced that, as part of the SIP, it was making an important contribution to the positive effect of the SIP on the process. We wanted to enlarge the raceway zone and break open blockages in the coke bed with strong shock waves. This would increase the permeability and consequently the efficiency of the blast furnace process with larger reaction surfaces.”

“At that time the project team at AT.PRO tec sat down with us and explained what they intended to do,” said Marcel Mokosch from Technical Sales at Schubert & Salzer Control Systems. “To generate impulses with even stronger shock waves, the high opening speeds had to be optimised still further in order to achieve extremely short opening times. In principle, sliding gate valves were the perfect choice for this application. The typical stroke between “open” and “closed” is only about 8 mm. This short stroke is accompanied by very small moved masses. For that reason, only small actuating forces are needed. As a result, the valve is ultimately even more compact than most other types of valve.”

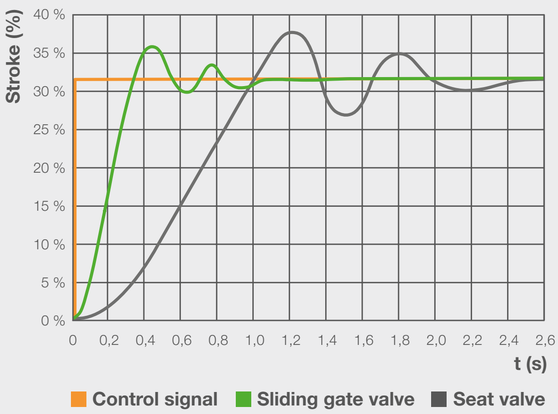
Following this meeting, the first “SIP box” - the prototype of the new system - ran for four to five years in continuous operation. In this time it was continually, further optimised. Over the years, step by step, the originally selected sliding gate valve design continued to develop together with the system and the process.

In close cooperation, the various design changes were made and then tested in practice in order to adapt the valve to the requirements of the application.

“Finally, we had managed to optimise the valve to a record opening speed of just 2 ms. This made it possible to generate impulses that reach deep into the coke bed with really strong shock waves,” said Marcel Mokosch. “However, the extremely fast switching speeds combined with high pressures and high switching frequency brought the valve to its load limits. This combination of requirements was really a challenge for us at the

Vitality:

Sliding gate control valves are considerably faster than conventional control valves. If you compare the stroke of two valves after a control signal step, it can be seen that the short stroke, the low actuating forces and the small actuator volume of the sliding gate control valves result in lower actuating times and a significantly smaller stroke amplitude in the transient condition. This high dynamism has a positive influence on the control quality of the whole control circuit.



time, but we also saw it as a great opportunity for the sliding gate technology to prove itself. In order to achieve valve service lives that were acceptable to the user under these extreme operating conditions, their mechanical limits had to be extended by design changes. The declared goal was a service life of one year, in other words several million switching cycles."

In 2015 the moment had finally arrived: thyssenkrupp Steel Europe and thyssenkrupp AT.PRO tec GmbH began with the development, installation and operation of a complete oxygen impulse process system on blast furnace 1 in Schwelgern. In the years that followed, the optimisation of the SIP boxes was finalised. SIP devices were installed on the 40 tuyeres of the blast furnace with the furnace in normal operation.

GS-Valve Type 8040 GS3 - The basis of a longstanding development partnership:
Over many years, the standard version of the sliding gate shut-off valve type 8040 GS3 was repeatedly adapted to the particular requirements of the application in the SIP boxes and then tested in practice.

„Finding such a persevering and reliable development partner is not a matter of course."
- Dr. Rainer Klock

Successful project completion

The SIP system was finally completed in autumn 2020. 40 SIP boxes were waiting to be used. The boxes were activated step by step over a period of several weeks. The effects on the process were awaited with excitement.

The SIP system on blast furnace 1 in Schwelgern has paid for itself in less than two years of operation and now saves costs amounting to several million Euros every year. Due to the increase in efficiency, the total consumption of reducing agents (coke and injection coal) has been significantly reduced. This is also reflected in the CO_2 savings of between 50 and 100 kg per tonne of pig iron produced, resulting in annual CO_2 savings in excess of 100,000 tonnes.

The entire project is a great success for thyssenkrupp AT.PRO tec: "After one and a half years of continuous operation, the Schubert & Salzer sliding gate valves have proven to be more than capable of coping with the extreme conditions of use in our application. The many years of joint development work with Schubert & Salzer has more than paid off. Finding such a persevering and reliable development partner is not a matter of course," explained Dr Rainer Klock, now the managing director of thyssenkrupp AT.PRO tec GmbH. "One of our future projects is now to enable further automated process optimisations by linking

View inside an SIP box: Two type-8040 sliding gate valves were further developed over the years so that they are capable of releasing the necessary impulses with strong shock waves and have a minimum service life of one year, i.e. several million switching cycles.

the SIP technology and the blast furnace process with the help of a Level 2 automation system. First of all, however, our goal will be to make the SIP technology a global success."

When the technology was fully operational for the first time, thyssenkrupp.AT.PRO tec decided that partnering with one of the leading blast furnace plant and equipment suppliers would be helpful in achieving this goal. In August 2021, after several months of negotiations, an exclusive worldwide marketing and sales agreement was signed with Primetals Technologies Ltd. "The intention is for our reliable partner Primetals Technologies to market this technology worldwide and to make it accessible to other steel manufacturers, too." concludes Dr. Rainer Klock.

The SIP results in a significant increase in the efficiency of the manufacture of pig iron; it saves costs amounting to several million Euros every year on blast furnace 1 in Schwelgern and has therefore paid for itself in less than 2 years of operation. The annual CO_2 savings amount to well over 100,000 tonnes.

About thyssenkrupp AT.PRO tec GmbH

thyssenkrupp AT.PRO tec is a provider of innovative technology for optimising melting processes in shaft furnaces in the steel and foundry industry. Our employees have decades of experience in the use of technical gases in melting processes and other industrial applications.

Our core competence is technical services, engineering, supply and installation of our SIP technology into existing customer systems, a total package from just one company.

The superiority of our technology has been developed through a research project in collaboration with academia and industry. The automated SIP process significantly improves the process cycles of various types of furnaces in a wide range of industries.

About Primetals Technologies

Primetals Technologies combines expertise in plant design and construction with great competence regarding the optimization of the steel-production process.

Global demand for iron and steel is constantly rising. At the same time, sourcing high-quality raw materials and satisfying energy needs can be a challenge. In this dynamic environment, steel plants have to utilize all available technologies to become greener and more environment friendly, and to improve their ecological footprint especially in terms of CO_2 emissions.

With this in mind, our latest focus areas include new ecological solutions for even greener steel production including the Sequence Impulse Process (SIP).

With thousands of references in ironmaking and steel-plant building and numerous partnerships worldwide, we support customers in setting new targets and shaping their future in the metals business.

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